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The Round Goby (*Neogobius melanostomus*) Invasion: Current Research and Future Needs

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Species native to Europe and Asia have invaded the Laurentian Great Lakes since the time of European settlement. The incidence of Eurasian invaders was accelerated in the 1840s with completion of the first passages by ocean-going vessels into the Great Lakes (Mills *et al*. 1993, 2000). The threat continues today primarily in the form of transoceanic cargo ships that can harbor Eurasian species within their ballast tanks. One of these species that invaded the Great Lakes from ballast transported from Eurasia is the round goby (*Neogobius melanostomus*), a small benthic fish native to the Black and Caspian seas.

This special topic section is devoted to the round goby. Of the two species of gobiids, the tubenose goby (*Proterorhinus marmoratus*) and round goby, that invaded the Great Lakes in 1990, it is the round goby that has proliferated and spread farthest. The tubenose goby is limited in its distribution to the St. Clair River, Lake St. Clair, Detroit River, several of their tributaries, one inland river (Running Creek; E. Holm, Royal Ontario Museum, personal communication), and sites along the north and south shore of western Lake Erie (Jude 2001). The round goby, however, has spread to all the Great Lakes and several of their tributaries, into three inland rivers in Michigan (Flint, Shiawassee, and Saginaw), into an inland river in Ontario (Running Creek; E. Holm, Royal Ontario Museum, personal communication), and down the Chicago Sanitary and Shipping Canal en route to the Mississippi River (Steingraeber *et al*. 1996). The round goby most likely has been able to spread to and proliferate in these habitats because of its tolerance for a wide range of environmental conditions, diverse diet that includes dreissenids, aggressive behavior, ability to spawn repeatedly throughout the spring and summer, parental care by males to facilitate successful recruitment, and large body size compared with

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species of a similar benthic lifestyle (Charlebois *et al*. 1997, MacInnis and Corkum 2000, Jude 2001).

The spread and proliferation of the round goby in North America raises concern about its potential impact on native species and ecosystem function. Thus far, the full range of potential impacts of the round goby has been difficult to predict because 1) literature from its native habitat and invaded areas is limited, and 2) existing research has not addressed many of the potential issues. This special topic section helps address those limitations. Most papers included in this section were presented at the Second International Round Goby Conference held in conjunction with the 1999 Annual Meeting of the International Association for Great Lakes Research in Cleveland, Ohio; other papers presented at that meeting have appeared elsewhere in print. The round goby conference was held to provide a forum for dissemination of current round goby research findings and to discuss the future direction of round goby research.

There is concern about the potential impact of the round goby on native fish species. Janssen and Jude (2001) documented the decline of the native mottled sculpin (*Cottus bairdi*) in southern Lake Michigan. Both species are benthic with similar ecological requirements for nesting, feeding, and shelter. Ultimate recruitment failure and subsequent demise of mottled sculpins most likely were caused by spawning interference by the round goby. French and Jude (2001) found that round goby diets overlapped significantly with some small benthic species in the St. Clair River and that round gobies will readily consume young-of-the-year (YOY), larval, and adult fishes, which could severely impact native fishes. Skora and Rzeznik (2001) also found that competition for food resources could impact native fishes in the Gulf of Gdansk (Baltic Sea). In this system, the round goby fed primarily on crustaceans, polychaetes, and bivalves, the preferred food of native fishes. However, in the Danube River basin, the round goby is mainly molluscivorous, feeding on *Dreissena polymorpha* (Dreissenidae), *Pisidium* spp. (Sphaeriidae), and *Anodonta* spp. (Unionidae) (Simonović *et al*. 2001). Clapp *et al*. (2001) found that the round goby has been expanding its range from nearshore rocky habitat and tributaries along Lake Michigan into the open waters of the lake. The depth range of the round goby, therefore, is overlapping that of the slimy (*C. cognatus*) and deepwater sculpins (*Myoxocephalus thompsoni*) with potential detrimental effects on spawning and already scarce benthic resources such as *Diporeia* spp., which are declining precipitously in Lake Michigan (Nalepa *et al*. 1998).

The round goby also may impact non-native species in the Great Lakes. Djuricich and Janssen (2001) examined the size distribution of zebra mussels exposed to and sheltered from round goby predation. They found that the largest zebra mussels were on the tops of rocks, while the smallest were beneath the rocks. They concluded that round gobies will reduce the size distribution of zebra mussels, but will not impact them dramatically, as many smaller individuals are still present to recruit and large females will remain to continue reproducing. Ray and Corkum (2001) showed that large round gobies force juvenile round gobies from preferred rocky habitats into less desirable sandy habitats from which the juveniles then dispersed.

It is generally believed that the round goby was brought to North America in ballast water originating from the Black Sea, the Caspian Sea, or the Gulf of Gdansk (Jude *et al*. 1992, Charlebois *et al*. 1997). In a genetic study of round goby specimens from these areas, Dillon and Stepien (2001) eliminated the northern Black Sea as a probable founding source for either the Great Lakes or the Gulf of Gdansk stocks. These authors contended the introductions were large or had multiple sources, and that the North American populations were closely related to each other, suggesting a common geographic origin.

The papers contained in this special topic section document the ability of the round goby to 1) compete with native fishes for common food resources, 2) prey on YOY, larval, and adult fishes, and 3) expand its range into new habitats. Although these findings have focused on the effects of the round goby on forage fish (mottled sculpin), diet studies of the round goby and other fishes indicate that the round goby will transfer energy through the food web. In addition, the ability of the round goby to consume zebra mussels may have changed bioaccumulation pathways for contaminants, which can negatively affect top consumers. Because the round goby has spread so quickly in both North America and Europe, it is essential to compare basic biological parameters, reproductive behaviors, and dispersal mechanisms of this species from different regions of the globe. Much of this information is still needed (Table 1). Large-scale and long-term ecological studies as well as manipulative experiments are needed to assess the ultimate effect of the round goby on freshwater and marine ecosystems.

TABLE 1. Round goby research needs as determined by attendees of the Second International Round Goby Conference. Research needs are not prioritized.

Age & Growth	Habitat	Management Options	Potential Impacts	Reproduction	Population Dynamics	Miscellaneous
Development of life table	Description of seasonal and annual movements	Evaluation of effectiveness of acoustics	Determination of change in flow of contaminants	Determination of hermaphrodite existence	Determination of dispersal mechanisms and environmental characteristics that limit dispersal	Genetic evaluation of colonizers
Comparison of age and growth rates from stable vs. expanding populations	Description of territoriality	Evaluation of effectiveness of parasites	Determination of effects on benthic communities	Determination of male invariably dies after spawning	Determination of maximum population based on habitat	Development of a key for *Neogobius* spp.
Analysis of cohorts	Description of habitat requirements	Evaluation of effectiveness of hormones	Comparison of effects in lotic and lentic systems	Quantification of nest density	Projection of standing stock	Development of an ethogram
	Description of habitat change and variability with age	Evaluation of effectiveness of sterile males	Determination of effects on zebra mussels	Quantification of nest and egg viability		Communication among researchers
	Description of site fidelity	Evaluation of effectiveness of removal	Determination of effects on nest spawners	Determination of nest success with multiple females		
		Evaluation of effectiveness of barriers	Determination of effects on anglers	Determination of factors for mate selection		
		Evaluation of effectiveness of outreach	Determination of effects on nearshore fishes	Determination of sexual discrimination		
		Correlate density sampling across methods and systems	Determination of energetic contribution to food web			
			Determination of effect of migration on food webs			
			Economic analysis of impacts			
			Documentation of realized impacts			

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